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(58) Field of Search

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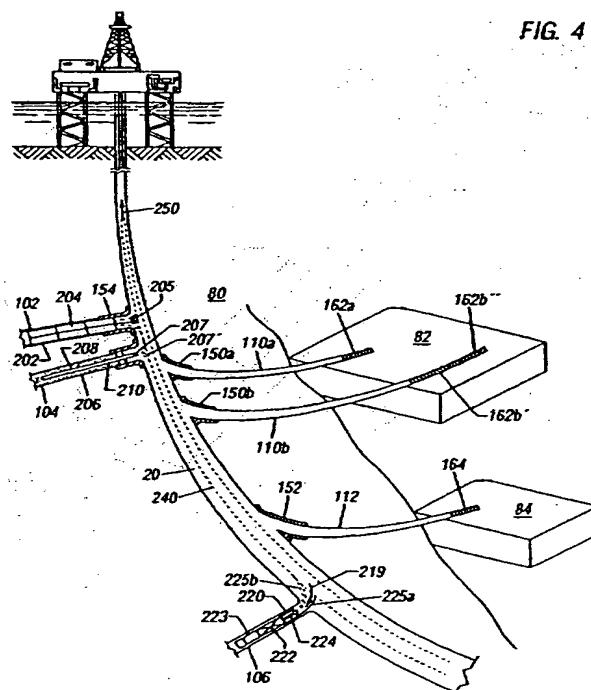
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(54) Abstract Title

Method of refining a hydrocarbon in a branch wellbore

(57) A branch wellbore 106 houses equipment 222 which may be utilised for processing hydrocarbons downhole. Such equipment may utilise stored materials 223, eg. chemicals and/or biological masses (enzymes). The production fluid may first be treated to remove any water and solids therefrom. The hydrocarbons may then be processed or treated to produce other materials, such as octane, benzene, toluene, methanol etc. The processing wellbores, such as wellbore 106, may be located at any location, such as above each producing branch wellbores 110a, 110b and 112. Additionally, multiple wellbores may be utilised to accomplish processing and treatment of the fluids downhole.



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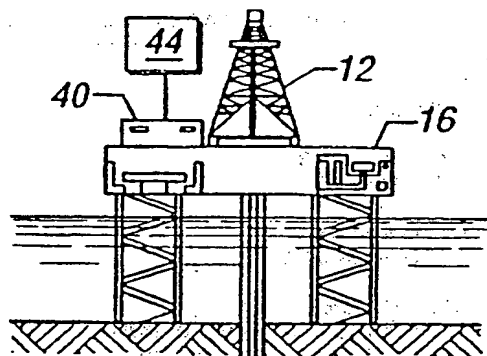


FIG. 1

20  
30  
32

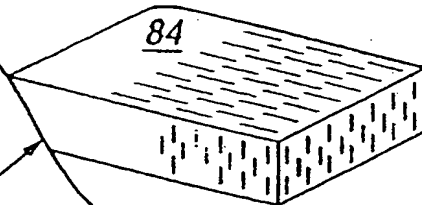
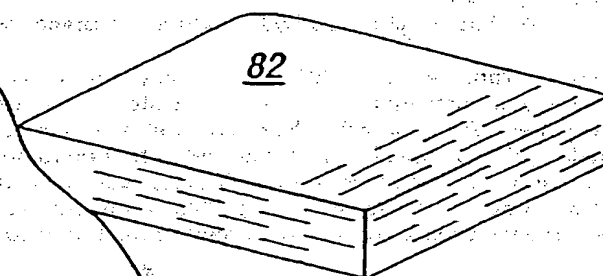
31

80

72

70

78



45

55

58b

68b

64

d

68a

58a

57

66a

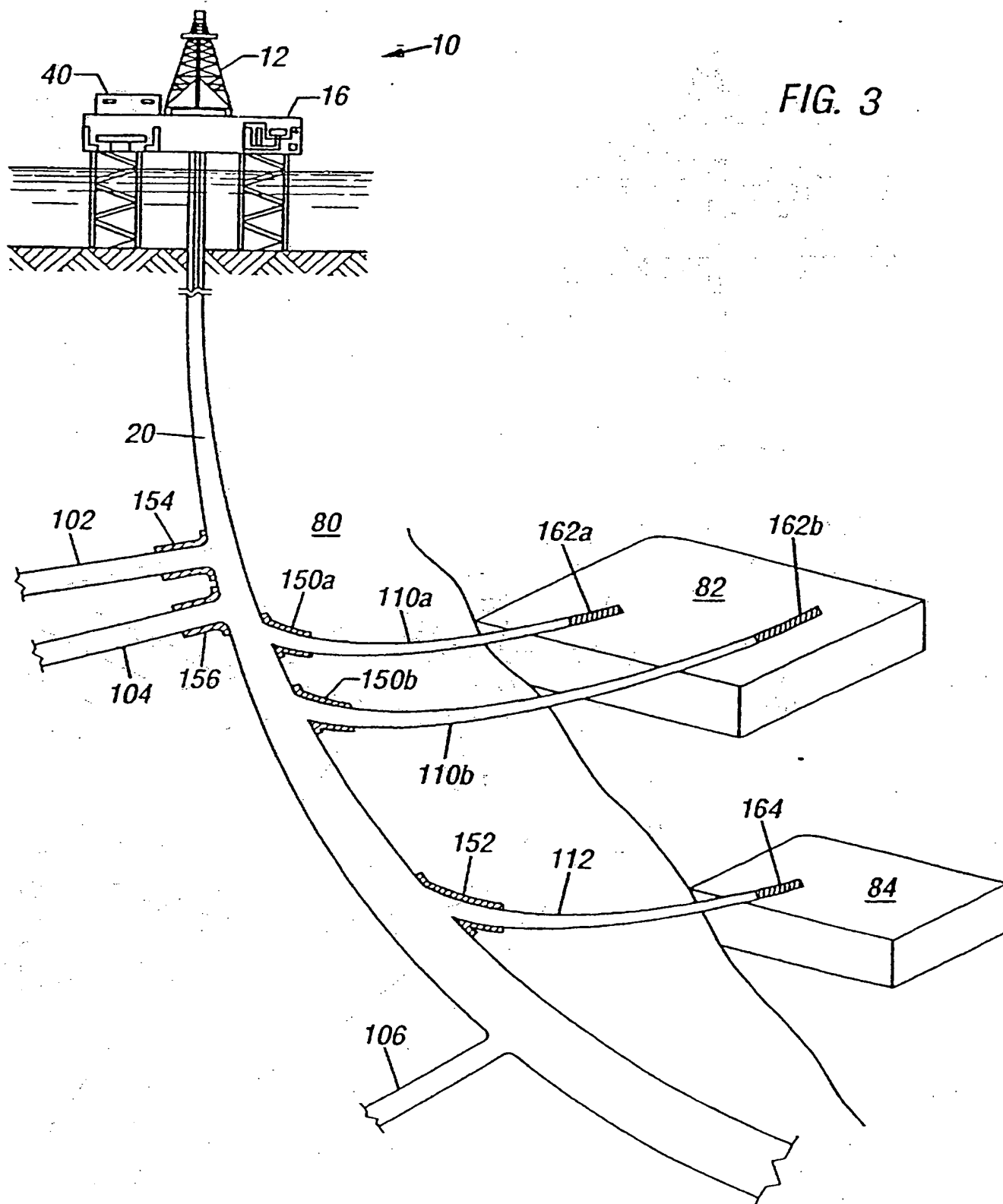
66b

65

74

50





**SUBSTITUTE SHEET (RULE 26)**

FIG. 4

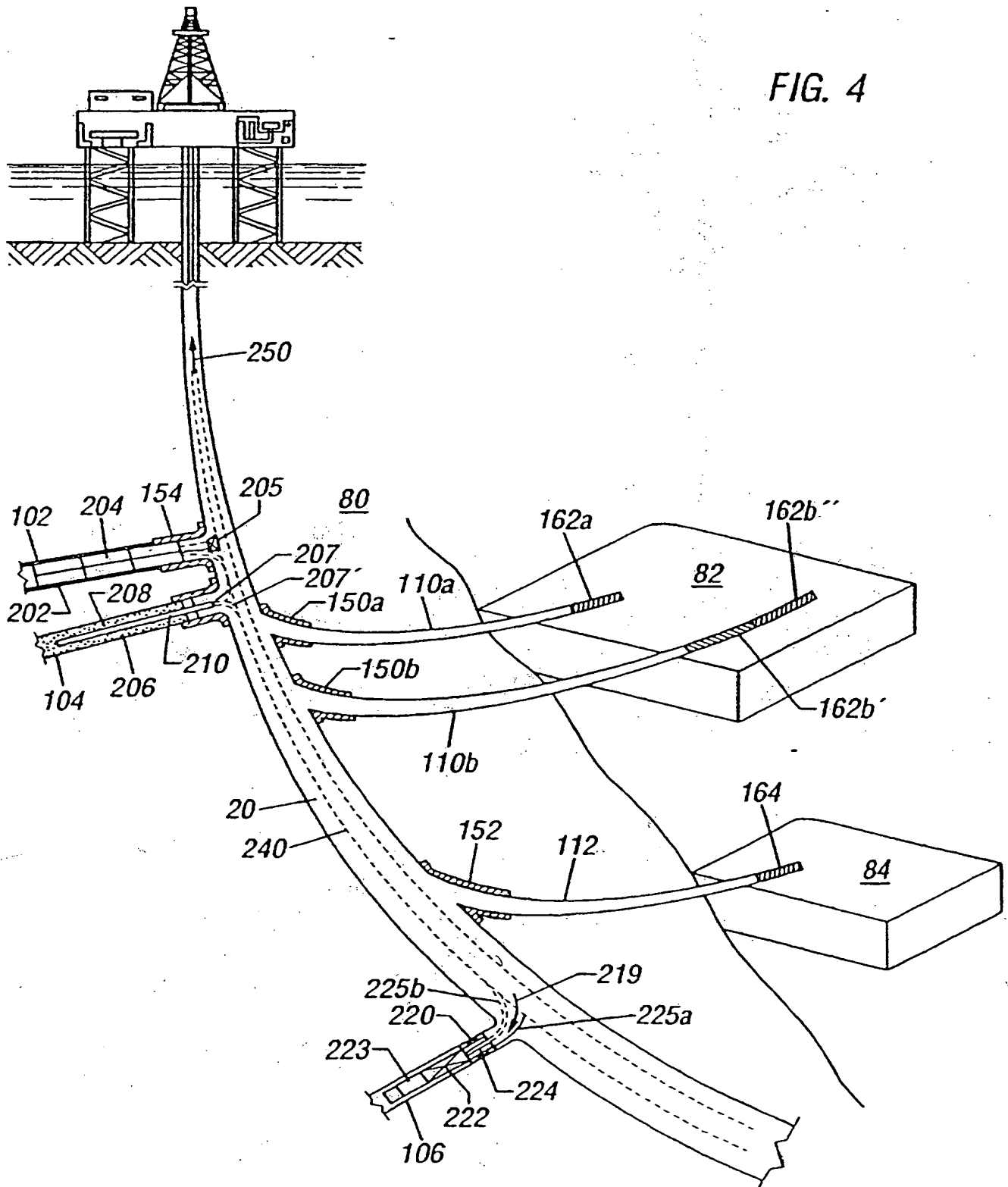


FIG. 5

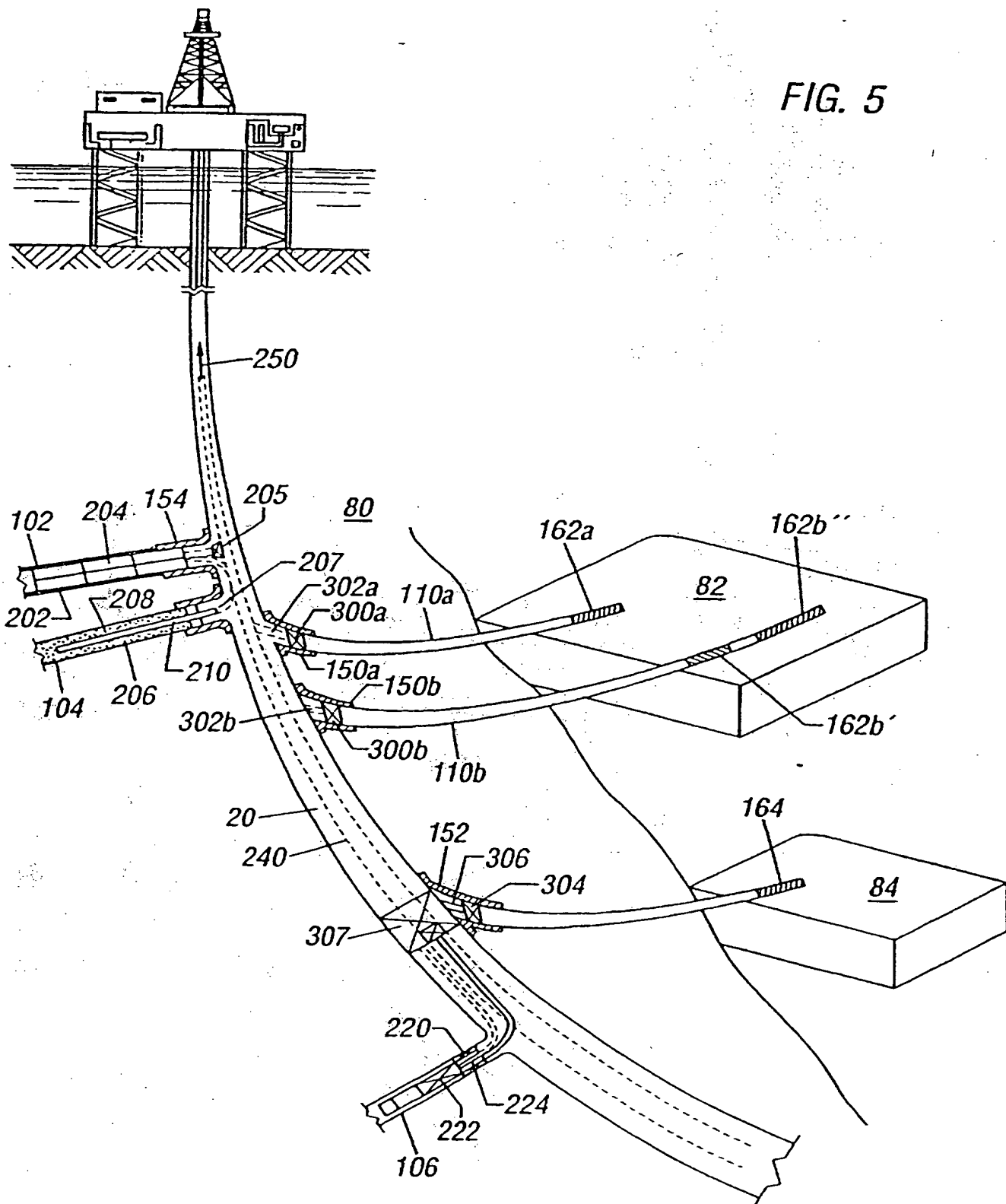




FIG. 7

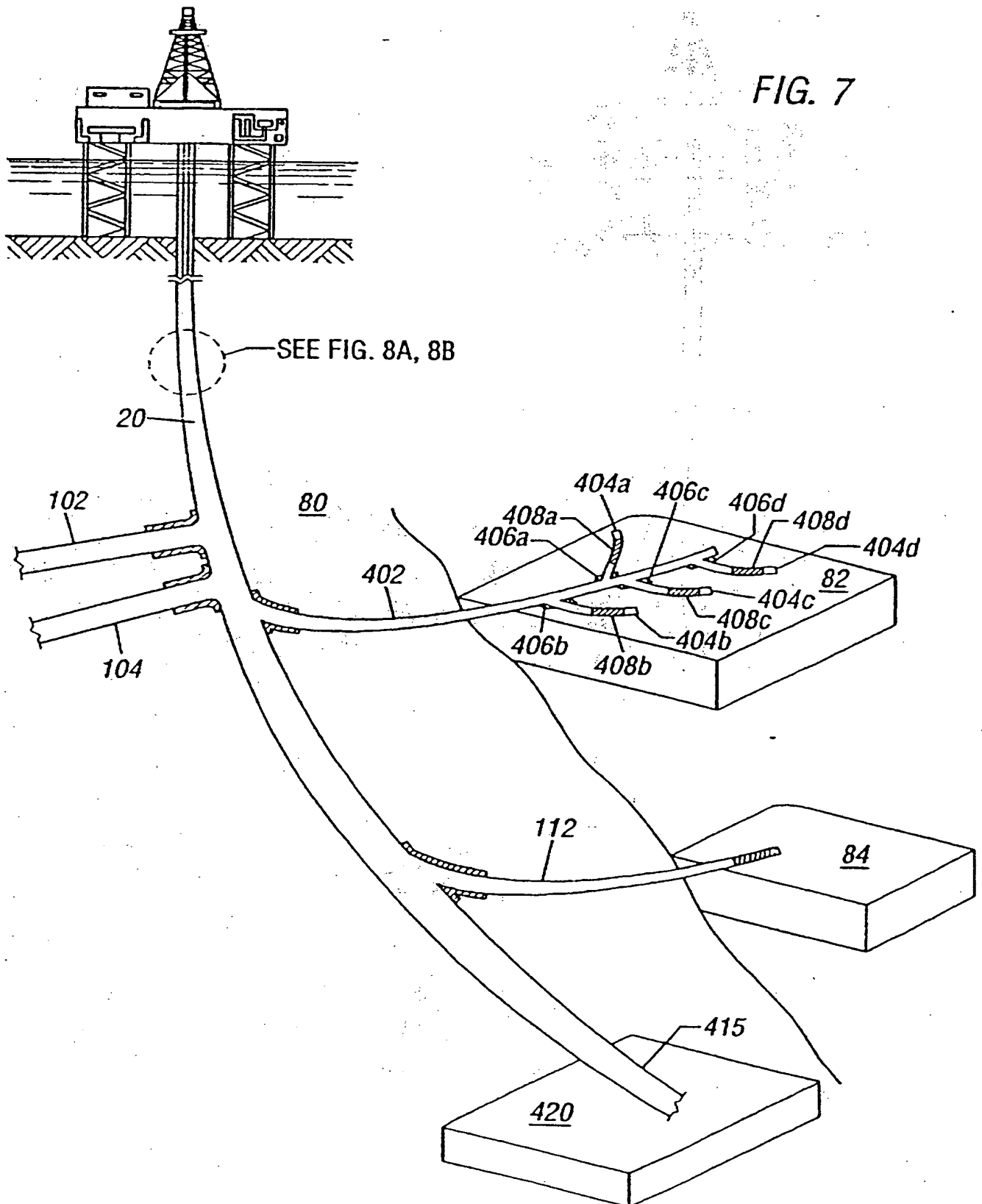




FIG. 8A

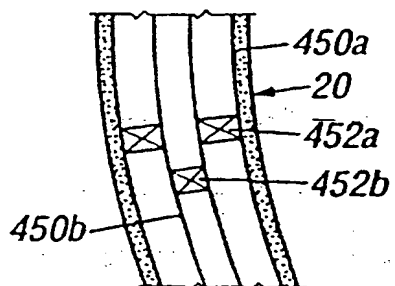


FIG. 8B

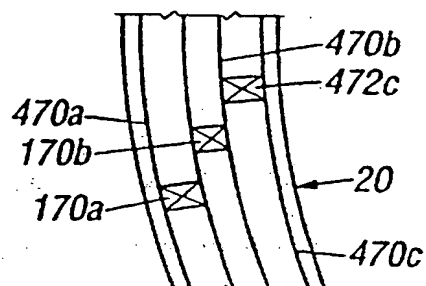


FIG. 9A

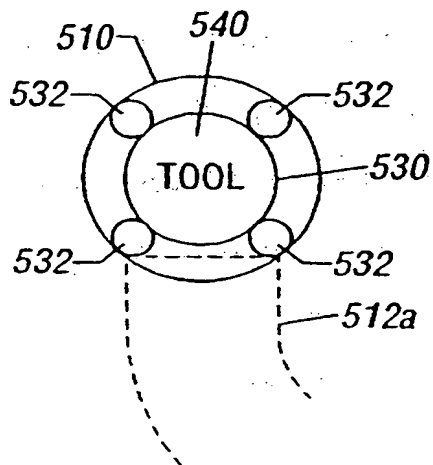
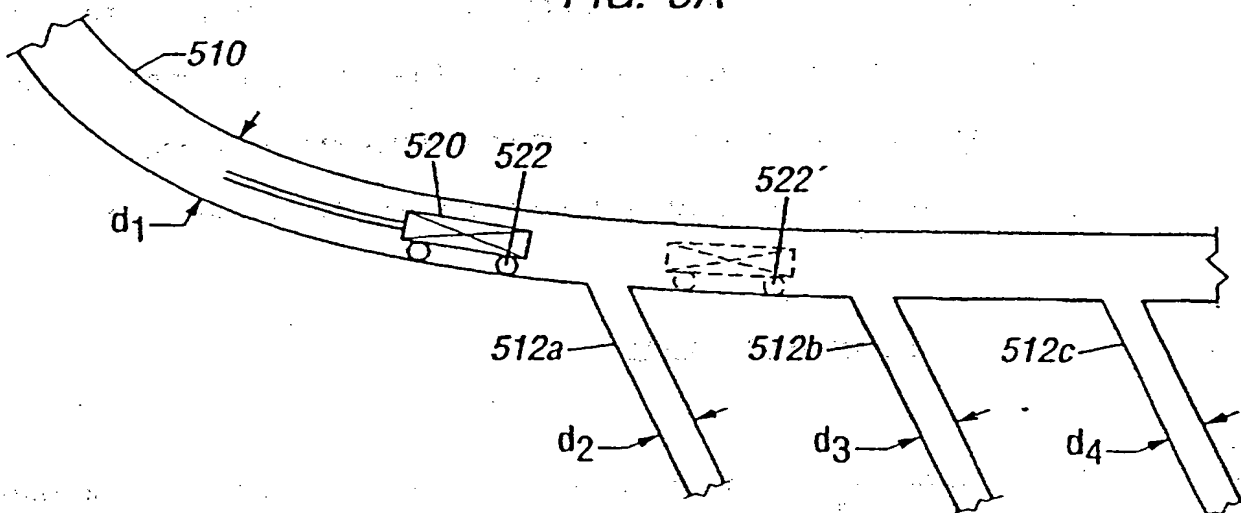


FIG. 9B

**Title: MULTI-LATERAL WELLBORE SYSTEMS  
AND METHODS FOR FORMING SAME**

**1. Field of the Invention**

5 This invention relates generally to wellbore construction and more particularly to methods for forming multi-branched or multi-lateral wellbores from one or more access wellbore. At least one access wellbore is formed substantially in non-producing subterranean formations. This invention also  
10 relates to methods of utilizing such wellbores, including utilizing the branch wellbores for storing various devices and materials for performing certain operations in the branch wellbores. This invention further relates to apparatus and method for transporting equipment and materials from a source location to a desired wellbore or between different wellbores.

15 **2. Background of the Art**

To obtain hydrocarbons such as oil and gas, wellbores (also referred to as boreholes) are drilled from one or more surface locations into  
20 hydrocarbon-bearing subterranean geological strata or formations (also referred to in the industry as the reservoirs). A large proportion of the current drilling activity involves drilling highly deviated and/or substantially horizontal wellbores extending through the reservoir. Typically, to drill a horizontal wellbore into a desired formation, the wellbore is drilled from a surface  
25 location vertically into the earth for a certain depth. At a predetermined

depth, the wellbore is dog-legged into a desired direction so as to reach the desired formation, which is usually the target hydrocarbon-bearing or producing formation. The wellbore is drilled horizontally into the producing formation to a desired length. Additional dog-legged wellbores from the same vertical wellbore are also drilled in some cases. Some horizontal boreholes extend several thousand meters into the reservoirs. In most cases, however, a single horizontal wellbore, generally referred herein as the primary wellbore, main wellbore or access wellbore, is drilled to recover hydrocarbons from different locations within the reservoir. More recently, branch wellbores from the main wellbore that extend into selected areas of the producing formation or reservoir have been drilled to increase production of hydrocarbons from the reservoir and/or to maximize the total hydrocarbon recovery from the reservoir. Such a branch wellbore herein is referred to as a lateral wellbore and a plurality of such branch wellbores extending from a wellbore are referred to as multi-lateral or multi-branched wellbores.

The primary wellbore and the multi-lateral wellbores are generally drilled along predetermined wellbore paths, which are usually determined or plotted based on existing data, such as seismic data and drilling data available from previously drilled wells in the same or similar formation. Resolution of such data is relatively low. To drill such wellbores, operators typically utilize a drill string which contains a drilling device and a number of measurement-while-drilling ("MWD") devices. The drilling device is used to disintegrate the subsurface formations and the MWD devices are used for

determining the properties of the formations and for determining the downhole drilling conditions. Operators utilize the information to adjust the drilling direction.

5 In many cases it is desirable to form a primary wellbore in a non-producing formation and then drill branch or lateral wellbores from the primary wellbore into the target formation. In such cases, it is highly desirable to place the primary wellbore along an optimum wellbore path which is at a known distance from the boundary of the target formations.

10 Prior art typically utilizes seismic data and prior wellbore data to decide upon the path for the primary wellbore. The resolution of such data is relatively poor. Wireline tools can be run to obtain the necessary bed boundary information. Wireline systems require stopping the drilling operations for several hours and are thus not very desirable. None of the prior art systems  
15 provide in-situ determination of the location of the boundary of the target producing formations relative to the wellbore being drilled. It is, thus, desirable to determine relatively accurately the location of the boundary of the target formation relative to the primary wellbore while drilling the primary wellbore. Such information can then be utilized to adjust the drilling direction  
20 to adjust the drilling direction to form the wellbore along an optimum wellbore path.

As noted above, current drilling methods and systems do not provide in-situ means for determining the position of the target formation bed

boundary relative to a primary wellbore that is drilled in a non-producing formation along the target formation. Current directional drilling systems usually employ a drill string having a drill bit at its bottom that is rotated by a motor (commonly referred to as the "mud motor"). A plurality of sensors and MWD devices are placed in close proximity to the drill bit to measure certain drilling, borehole and formation evaluation parameters. Typically, sensors for measuring downhole temperature and pressure, azimuth and inclination measuring devices and a formation resistivity measuring device are employed to determine the drill string and borehole-related parameters. However, none of these systems allow drilling an access wellbore at a known distance from the wellbore that is determined and adjusted while the access wellbore is being drilled.

United States Patent Application Serial No. 60/010,652, filed on January 26, 1996, which is assigned to the assignee of the present application and which is incorporated herein by reference, provides a system for drilling boreholes wherein the downhole subassembly includes an acoustic MWD system in which a first set of acoustic sensors is utilized to determine the acoustic velocities of the borehole formations during drilling and a second set of acoustic sensors for determining bed boundary information based on the formation acoustic velocities measured downhole. Isolators between the transmitters and their associated receivers serve to reduce the body wave and tube wave effects. The present invention preferably utilizes the system disclosed in the United States Patent

Application Serial No. 60/010,652 to determine the location of the bed boundaries around the primary wellbore, including the bed boundaries of the target reservoir relative to the primary wellbore while drilling the access wellbore. The drilling direction or path of the primary wellbore is adjusted based on the bed boundary information to place the primary wellbore at optimum distance from the target formation. Since the location of the primary wellbore is relatively accurately known in relation to adjacent formations, it enables drilling branch wellbores along optimum paths into the target formation and the non-producing formations.

In the prior art primary wellbores, a number of devices are placed to facilitate production of hydrocarbons and to perform workover services. Such devices occupy space in the primary wellbore, which may be utilized for improving the overall efficiency of the wellbore system. Such primary wellbores are expensive to construct, are relatively inefficient in transporting hydrocarbons and are obstructive if major workover is required after the completion of such wellbores. It is desirable to have branch wellbores for storing various types of equipment and materials downhole, including retrievable devices which may be utilized for performing downhole operations. It is also desirable to leave the primary wellbore substantially free of any equipment and materials which may be placed outside the main wellbore and to utilize the main wellbore primarily for transporting fluids during the production of hydrocarbons. This may be accomplished by

storing certain devices in the storage wellbore and by installing the fluid flow control devices entirely in the individual branch wellbores.

5 It is a common practice to form a seal around an area at the intersection of the primary wellbore and the branch wellbores. The seal is usually formed between the intersecting wellbores and the formation. Since the prior art branch wellbores are formed from the primary wellbores placed in the producing formations, the seals are formed entirely within such producing formations. Seals formed in the producing formations tend to be  
10 less durable because such formations typically are relatively porous and also because of the presence of depleting hydrocarbons. It is therefore desirable to form such seals entirely within the non-producing formations.

United States Patent Applications Serial No. 08/411,377, filed March  
15 27, 1996 and Serial No. 08/469,968, filed June 6, 1995, both assigned to the assignee of this application, which are incorporated herein by reference in their entirety, disclose forming branch wellbores from a primary wellbore, wherein some of the branch wellbores are drilled outside producing formations or the reservoirs for storing chemicals for treating the  
20 hydrocarbons downhole and for re-injecting water into secondary formations.

Such wellbore construction solves some of the problems with the above-noted prior art wellbore. However, these methods do not provide wellbores for storing retrievable devices therein which may be utilized downhole at a later time, such as for performing completion operations, perforating, or

performing workover tasks or transferring certain chemicals from such storage wellbores to another location downhole during the drilling of branch wellbores or at a later time, such as after the hydrocarbon production has started. Additionally, such wellbores do not provide for forming seals which  
5 lie outside the producing wellbores or primary wellbores which are utilized primarily for transporting fluids during the production phase.

The present invention addresses the above-noted problems associated with formation and use of multi-lateral wellbores and provides  
10 methods for forming multi-lateral wellbores from a primary wellbore which is formed substantially in a non-producing formation. The distance between the primary wellbore and the target formations is determined while drilling the primary wellbore, preferably by acoustic means. The drilling path of the primary wellbore is altered or adjusted based on the in-situ distance  
15 measurements to place the primary wellbore along an optimum path. The lateral wellbores are drilled from the primary wellbore in the non-producing formations and producing formations. Seals are formed at the intersection of the lateral wellbores and primary wellbore entirely in the non-producing formation. Lateral wellbores are utilized for a variety of purposes, including  
20 for storing equipment and for processing and treating fluids downhole. Fluid flow control devices are placed outside the primary wellbore. The primary wellbore is utilized primarily for flowing the hydrocarbons.



## SUMMARY OF THE INVENTION

The present invention provides methods and systems for forming multi-lateral wellbores. In one method, a primary or access wellbore is formed substantially in a non-producing formation. At least one production branch wellbore is formed from the access wellbore into a hydrocarbon-bearing formation for recovering hydrocarbons from such a formation. At least one branch wellbore is formed for storing retrievable apparatus which may be utilized later for performing an operation downhole. Additional lateral wellbores may be formed from the access wellbore or the branch wellbores for storing therein materials and equipment which may be utilized downhole later. One such branch wellbore may be formed for storing certain chemicals that are selectively discharged into the hydrocarbons during production. Another branch wellbore may be formed to contain a fluid separation system for separating downhole hydrocarbons into different phases or for separating hydrocarbons from other fluids such as water.

The present invention provides for forming seals between the access wellbore and the production wellbores entirely in the non-hydrocarbon bearing formations. Additionally, flow control apparatus for controlling fluid flow from the producing formations through the production branch wellbores may be located entirely outside the access wellbore to facilitate the fluid flow through such production branch wellbores.

The production branch wellbores and other branch wellbores are completed. Hydrocarbons then flow from the producing formations into their associate production wellbores. Such multi-lateral wellbore construction  
5 allows utilizing the access wellbore for primarily transporting fluids during production of hydrocarbons and provides more access space for remedial and or service operations.

In another method of the present invention, the distance between the  
10 access wellbore and the producing formations is determined during the drilling of the access wellbore. In one method acoustic sensors deployed in a drilling assembly are utilized for determining the distance between the access wellbore and the desired formations. In an alternative method seismic  
15 measurement are utilized for determining such distance while drilling the access wellbore. The distance determined may be utilized for adjusting the drilling path of the access wellbore either from the surface or by deploying devices that would automatically adjust the drilling direction based on the computed distance.

20 The methods of the invention provide for retrieving the stored devices in the branch wellbores for performing a function downhole. The stored devices may include devices for drilling wellbores, for perforating wellbores, for performing wellbore completion operations, for performing workover operations and for taking wellbore measurements.

The present invention further provides a system for transporting devices or materials to and from any desired branch wellbore.

5 Examples of the more important features of the invention have been summarized rather broadly in order that the detailed description thereof that follows may be better understood, and in order that the contributions to the art may be appreciated. There are, of course, additional features of the invention that will be described hereinafter and which will form the subject of  
10 the claims appended hereto.

#### BRIEF DESCRIPTION OF THE DRAWINGS

For detailed understanding of the present invention, references should  
15 be made to the following detailed description of the preferred embodiment, taken in conjunction with the accompanying drawings, in which like elements have been given like numerals, wherein:

20 FIG. 1 shows a schematic illustration of forming an access wellbore in a non-producing formation while determining the location of the target formations relative to the access wellbore.

FIG. 2 is a schematic diagram showing the formation of lateral wellbores formed from the primary access wellbore at selected places into the non-producing and producing formations.

5 FIG. 3 is a schematic diagram showing the formation of seals at the intersection of the primary wellbore and the branch wellbores that are placed entirely in the non-producing formation.

10 FIG. 4 shows the placement of retrievable devices in a branch wellbore, chemicals in a separate branch wellbore and processing apparatus in yet another separate branch wellbore, thereby enabling utilizing the access wellbore primarily or entirely for flowing fluids therethrough.

15 FIG. 5 is a schematic diagram showing the placement of flow control apparatus outside the primary wellbore.

20 FIG. 6 is a schematic diagram showing the formation of interconnecting access wellbores in a non-producing and producing formation, wherein lateral production wellbores are formed from the access wellbore in the producing formation.

FIG. 7 is a schematic diagram showing a primary access wellbore which avoids certain producing formations and which is drilled into a certain producing formation.

FIG. 8A is a schematic diagram of the primary access wellbore with a multi-concentric tubing for flowing fluids therethrough.

FIG. 8B is a schematic diagram of the primary access wellbore with multiple tubings placed therein for flowing fluids therethrough.

FIG. 9A is a schematic diagram of a transport system for use in placing devices and materials in the branch wellbores.

FIG. 9B is a side of the transport system of FIG. 9A.

#### DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

In general, the present invention provides methods and systems for forming multi-lateral wellbores from one or more primary access wellbores. FIGS. 1-5 illustrate the formation of lateral wellbores from an access wellbore that is formed primarily in a non-producing formation. FIGS. 6 and 7 illustrate examples of forming branch wellbores from access wellbores formed in both a non-producing and a producing formation. Branch wellbores made from a single access wellbore are first described followed by the formation of branch wellbores from multiple access wellbores. Apparatus and method for transporting devices and materials into the wellbores is described thereafter.

FIG. 1 shows a schematic diagram of a preferred drilling system 10 for drilling wellbores offshore. The drilling system 10 includes a drilling platform 12, a drill string 30 having a drilling apparatus and various measurement-while-drilling ("MWD") devices at its bottom end. The combination of the drilling apparatus and the MWD devices are sometimes referred to herein as the "downhole assembly" or the "bottomhole assembly" or "BHA" and is denoted numeral 45. The bottomhole assembly 45 is utilized for drilling an access wellbore 20 through the subterranean formations and for making measurements relating to the subsurface formations and drilling parameters during the drilling of the access wellbore 20. The drilling platform 12 includes a derrick 14 erected on a floor 16 which supports a rotary table rotated by a prime mover (not shown) at a desired rotational speed. The drill string 30 includes a tubing 32 that extends downward from the rotary table into a primary or main access wellbore 20. A bottomhole assembly 45 is attached to the bottom end of the tubing 32 for drilling the wellbore 20. The drill string 30 is coupled to a drawworks via a kelly joint, swivel and line through a system of pulleys to hold the drill pipe 32. Such elements are well known in the art for forming wellbores and are, thus, not shown or described in any detail.

A control unit 40 is preferably placed on the platform 12. The control unit 40 receives signals from the MWD devices and other sensors placed downhole and on the surface, processes such signals, and aids in controlling

the drilling operations according to programmed instructions. The surface control unit 40 includes devices for displaying desired drilling parameters and other information, which information is utilized by an operator to control the drilling operations. The surface control unit 40 contains a computer, memory for storing data, data recorder and other peripherals. The surface control unit 40 also includes models and processes data according to programmed instructions and responds to user commands entered through a suitable means, such as a keyboard. A number of alarms 44 are coupled to the control unit 40, which selectively activates such alarms when certain unsafe or undesirable operating conditions occur. Such control systems are known in the art and, thus, are not described in detail.

The bottomhole assembly 45 preferably includes a drill motor or mud motor 55 coupled to a drill bit 50 via a drive shaft (not shown) disposed in a bearing assembly 57 for rotating the drill bit 50 when a fluid 31 is passed through the mud motor 55 under pressure. A lower stabilizer 58a is provided near the drill bit 50, which is preferably placed over the bearing assembly 57, to acts as a centralizer for the lowermost portion of the bottomhole assembly 45. Additional stabilizers, such as a stabilizer 58b, are suitably placed along the bottomhole assembly for providing lateral support to the bottomhole assembly 45 at desired locations.

Still referring to FIG. 1, the BHA preferably contains a formation resistivity device 64 for determining the formation resistivity near and in front of the drill bit 50, a gamma ray device 65 for measuring the formation gamma ray intensity and an inclination measuring device (inclinometer) 74 for determining the inclination and azimuth of the bottomhole assembly 45. The resistivity device 64 contains one or more pairs of transmitting antennae 66a and 66b spaced from one or more pairs of receiving antennae 68a and 68b. Magnetic dipoles are employed which operate in the medium frequency and lower high frequency spectrum. In operation, the transmitted electromagnetic waves are perturbed as they propagate through the formation surrounding the resistivity device 64. The receiving antennae 68a and 68b detect the perturbed waves. Formation resistivity is derived from the phase and amplitude of the detected signals. Signals from these devices and other sensors are processed by a downhole circuit and transmitted to the surface control unit 40 preferably a suitable two-way telemetry system 72.

The inclinometer 74 and the gamma ray device 76 are preferably placed along the resistivity measuring device 64 for respectively determining the inclination of the portion of the drill string near the drill bit 50 and the formation gamma ray intensity. Any suitable inclinometer and gamma ray device may be utilized for the purposes of this invention. In addition, an azimuth device (not shown), such as a magnetometer or a gyroscopic device, may be utilized to determine the drill string azimuth. Such devices are known



in the art and, thus, are not described in detail herein. In the above-described configuration, the mud motor 55 transfers power to the drill bit 50 via one or more hollow shafts that run through the resistivity measuring device 64. The hollow shaft enables the drilling fluid to pass from the mud motor 55 to the drill bit 50. In an alternative embodiment of the drill string 20, the mud motor 55 may be coupled below resistivity measuring device 64 or at any other suitable place.

The downhole assembly 45 preferably includes a section 78 which contains an acoustic system 70 for determining the distance between the access wellbore 20 and adjacent formations, such as target or producing (hydrocarbon-bearing) formations 82 and 84. Producing formations are also referred herein as reservoirs. The acoustic system contains transmitters and one or more sets of receivers (not shown). The system is adapted to transmit acoustic signals at a desired number of frequencies or by sweeping frequencies in a given range. The transmitted acoustic signals reflect from the formations 82 and 84 and the reflected signals are detected by the receivers. The detected signals are processed to determine the distance "d" between the access wellbore and the target formations. The frequencies of the transmitted signals are chosen to obtain a desired depth of investigation and the resolution. Such a method enables in-situ determinations of the distance between the bed boundaries of the target formations 82 and 84 from the bottomhole assembly 45.

United States Patent Application Serial No. 60/010,652, which is assigned to the assignee of this invention and which is incorporated herein by reference in its entirety, discloses an acoustic system for determining the bed boundaries from a bottomhole assembly. The present invention preferably utilizes such an acoustic system for determining the distance  $d$ . The present invention, however, may utilize any other known system for determining the bed boundary information. Such systems may include seismic methods in which receivers are deployed in drill string or the BHA and a source is placed at the earth's surface or vice versa.

Still referring to FIG. 1, the section 78 also includes devices for determining the formation density, formation porosity and other desired formation evaluation parameters. The section 78 is preferably placed above the mud motor 55. Such devices are known in the art and the present invention may utilize any such devices. These devices also transmit data to the downhole telemetry system 72, which in turn transmits the received data uphole to the surface control unit 40. The downhole telemetry system 72 also receives signals and data from the uphole control unit 40 and transmits such received signals and data to the appropriate downhole devices. The present invention preferably utilizes a mud pulse telemetry technique to communicate data from downhole sensors and devices to the control unit 40 during drilling operations. Any other communication system also may be utilized.

Still referring to FIG. 1, in one method of forming wellbores, the drilling system 10 is utilized to drill the access wellbore 20 through a non-producing or non-hydrocarbon-bearing formation 80 along a predetermined wellbore path a certain distance from the hydrocarbon-bearing formations, such as formations 82 and 84. Such a predetermined wellbore path is typically defined based on prior information, such as seismic data and data relating to prior wellbore formed in the same or nearby geological formations. During the drilling of the access wellbore 20, the acoustic device 70 continually determines the distance  $d$  between the wellbore 20 and the target formations 82 and 84. As noted earlier, prior art systems do not attempt to drill the access wellbores primarily in a non-producing formation and also do not determine the relative location of the target formations while drilling the access wellbore. In the present invention, the bed boundary information obtained by the bottomhole assembly 45 is preferably utilized to adjust the drilling direction of the access wellbore 20 from the surface or by deploying self-adjusting apparatus downhole that may be controlled from the surface or which is self-actuating based on the distance  $d$  determined by the bottomhole assembly 45 and the desired distance. Such method enable drilling the access wellbore along an optimal wellbore path and enables adjusting the drilling path bases on relatively accurate in-situ measurements taken during the drilling operations.

Typically, the access wellbore, such as the wellbore 20, is substantially larger than the lateral wellbores that are to be drilled from the access wellbore. Therefore, access wellbores require use of large rigs, which are expensive to operate. Therefore, it is desirable to first drill the access wellbore to a sufficient distance from the surface and then drill lateral wellbores by utilizing smaller rigs, which are usually referred to as the workover rigs.

The access wellbore 20 is preferably formed entirely or substantially entirely in non-producing formations for reasons which are more fully explained later. Once the access wellbore 20 has been formed to a desired depth, a desired number of non-production lateral or branch wellbores are formed from the access wellbore 20. As an example and not as a limitation, FIG. 2 shows an example of forming non-production branch wellbores. Non-production branch wellbores 102, 104 and 106, each having a desired reach or depth, are shown formed from the access wellbore 20 into the non-producing formation 80. Wellbores 102, 104 and 106 respectively intersect the wellbore 20 at locations 103, 105, and 107. The non-production branch wellbores may also be formed from production branch wellbores 110 and 112. The non-production wellbores may be utilized for a variety of purposes as explained in more detail later with reference to FIGS. 4 and 5.

It is desirable to form the branch wellbores in a non-producing formation because they usually are less porous than the producing formations and are, thus, harder than the producing formations. The non-producing formations, thus, enable forming stronger and more durable wellbores less expensively. Some of such wellbores, however, may be formed in the producing formations. In addition to the desired non-production wellbores 102, 104, and 106, a desired number of production wellbores are formed from the access wellbore 20 into the producing formations 82 and 84. As an example, and not as any limitation, FIG. 2 shows the formation of two production wellbores 110a and 110b respectively from locations (points of intersection) 111a and 111b at the access wellbore 20 into the producing formation 82. Similarly, a production branch wellbore 112 is formed from the access wellbore 20 into the producing formation 84. Knowing the distance of the producing formations 82 and 84 from the access wellbore 20 enables planning and drilling the branch wellbores 110a, 110b and 112 along optimum wellbore paths.

It is known in the art that it is desirable to drill the wellbores in the producing formations, such as formations 82 and 84, with a drilling fluid that is different from the fluid utilized for drilling the wellbores or portions thereof in the non-producing formations. This is due to the fact that commonly used drilling fluids for drilling wellbores through the non-producing formations can cause productivity impairment in the producing formations. If this occurs, this

usually requires stimulating the formation to allow the producing formation to reach its maximum potential.

The fluids used for drilling in the producing formations are referred to in the art as the "drill-in" fluids. Current methods require having two complete fluid systems. The wellbore fluid is changed each time a wellbore is drilled into a producing formation. In the example of FIG. 2, the drilling fluid would be changed when the branch wellbore 110a is drilled past the location 110a'.

The drilling fluid will again be changed when the branch wellbore 110a has been drilled and the drilling is continued to drill the access wellbore 20 past the branch wellbore 110a. Thus, for the purpose of this invention, it is preferred that the wellbores, both the access wellbore and the branch wellbores, first be formed in the non producing formations to the extent practical by utilizing one type of drilling fluid and then changing the fluid to drill the branch wellbores in the producing formations. Thus, the present invention requires changing the drilling fluid only once, i.e., after the access wellbore and other branch wellbores have been drilled into the non-producing formations to the extent practical.

After drilling the branch wellbores as described above, seals are formed at respective branch wellbore junctions with the access wellbore 20. FIG. 3 shows the formation of such seals. As shown, seals 154 and 156 are respectively formed at the intersection of the access wellbore 20 and the non-production branch wellbores 102 and 104. It may be desirable not to form

any seal between certain branch wellbores and the access wellbore 20 as shown for the branch wellbore 106. Similarly, seals are formed between the access wellbore 20 and the production branch wellbores 110a, 110b and 112. As noted earlier, since the rocks are usually harder in the non-producing formations, such as the formation 80, it is preferred that the seals for the production wellbores, such as wellbores 110a, 110b and 112, are formed entirely in the non-producing formation 80. Such seals are easier to form and are more durable. Various types of seals and methods of forming seals are known in the oil and gas industry. For the purpose of this invention any such seals may be formed.

Still referring to FIG. 3, the production wellbores are completed at desired zones. For example, wellbore 110a is completed at zone 162a for producing hydrocarbons from the formation 82. Additionally, the wellbore 110b is completed at two locations 162b' and 162b'' for producing additional hydrocarbons from the formation 82. Similarly, wellbore 112 is shown completed at a zone or location 164 for producing hydrocarbons from the formation 84. It should be noted that any number of wellbores may be formed in each of the producing formations and each such wellbore may be completed at any number of zones for optimizing the production of hydrocarbons. Furthermore, any suitable completion method may be utilized for performing completion operations.

FIG. 4 shows the completion of non-production wellbores 102, 104 and 106 and some examples of how such wellbores may be utilized. Wellbore 102 is shown to contain a liner or casing 202 for protecting the wellbore from collapsing. In certain hard formations and/or certain shallow wellbores, it may not be necessary to use such methods for protecting the wellbore. In FIG. 4, wellbore 102 is shown as a place for storing devices. The stored devices are denoted generally by numeral 204. Once the desired number of storage wellbores, such as wellbore 102, have been suitably completed, devices 204 may be conveyed into and retrieved therefrom as desired. As shown in FIG. 4, devices 204 may be conveyed into the storage wellbores 102 via a casing 240 placed in the access wellbore 20 and a suitable closable opening 205 between the access wellbore 102 and the casing 240 by any suitable method, including by coiled tubings. The devices 204 may be self-propelled and may be activated from a remote location, such as the surface or a location in any of the wellbores via a suitable communication apparatus. Thus, such a device would contain certain amount of local intelligence. The devices 204 may be programmed to self-actuate upon the occurrence of a condition to perform an operation downhole. Thus, the devices 204 may be autonomous. The devices 204 may be retrieved from the wellbore 102 for performing a suitable operation downhole. Examples of the devices that may be stored in the storage wellbores include: (a) bottomhole assemblies, which may include a drill bit, drilling motor and measurement-while drilling devices (b) individual measurement-while-drilling



devices and/or other sensors for use in determining formation, drilling, wellbore and production parameters, (c) devices for use in completing wellbores, (d) perforating devices, (e) packers, (f) compressors; (g) pumps; (h) perforating devices; (i) flow control devices; and (j) other devices that may be utilized downhole during the formation of the wellbores described above and/or for later use during the production of hydrocarbons from the target formations.

Still referring to FIG. 4, the non-production branch wellbore 104 has a junction 154 and is lined with a casing 206. This wellbore is shown to house materials 208, which may be utilized for processing or treating fluids downhole. The stored materials 208 may include chemicals and/or biological masses (enzymes). The chemicals and/or biological masses may be utilized for treating downhole fluids to alter the viscosity, to change the chemical composition or chemical make-up of fluids downhole, i.e., in one of the wellbores. In practice, to treat the downhole fluids with the stored materials, such materials may be controllably released into the access wellbore 20 through a release path 210 and a suitable control device 207. Alternatively, the fluids from the access wellbore 20 may be passed into the wellbore 104 via a suitable line 207' for treatment with the stored materials. The treated fluids may then be returned to the access wellbore 20 via the fluid control device 207. The fluids may be treated to alter the viscosity of the downhole fluids so as to reduce drag, change the chemical structure and/or chemical make-up of the downhole fluids, including the hydrocarbons.

In FIG. 4, the branch wellbore 106 is shown to contain equipment 222 and materials for processing and/or treating fluids downhole. Additionally, materials, such as chemicals and biological masses, generally denoted by numeral 223, may also be stored for use with the equipment 222. The fluids 219 may be passed from the access wellbore 20 into the wellbore 106 via suitable conduit 225a. The equipment 222 treats or processes the received fluids 219 and discharges the treated fluids either back into the access wellbore 20 or to another wellbore (not shown). The equipment 222 may include equipment for separating downhole fluids into various constituents, such as solids, water, oil and gas. In one embodiment, water may be separated from oil and gas. The separated water may be discharged into a dump wellbore (not shown) and the oil and gas may be returned to the access wellbore 20 for transportation to the surface. This allows for more efficient transportation of hydrocarbons from the producing formations.

In another embodiment, the wellbore 106 the equipment 222 may include equipment and for processing hydrocarbons downhole. Such equipment may utilize chemicals or other materials 223 for processing the hydrocarbons. As an example, production fluid may first be treated to remove any water and solids therefrom. The hydrocarbons may then be processed or treated to produce other materials, such as octane, pentane, toluene, benzene, methanol, naphtha, fuel oil, gasoline, diesel, jet fuel, lube oil, asphalt, etc. Processing equipment, chemicals and/or biological masses 223

may be utilized to produce such materials. It should be noted that the processing wellbores, such as the wellbore 106, may be located at any other desired location, such as above each of the producing branch wellbores, such as wellbores 110a, 110b and 112. Additionally, multiple wellbores may be utilized to accomplish the processing and treatment of the fluids downhole.

For example, one wellbore may be utilized to remove solids and water from the fluids and another wellbore for treating and/or processing the hydrocarbons. Thus, one of the purposes of such wellbores may be to eliminate or reduce the processing of fluids and/or hydrocarbons on the surface. Additionally, heating equipment and electrical equipment may be utilized in a branch wellbore to treat /or alter the state of a fluid downhole.

Still referring to FIG. 4, the branch wellbores, such as wellbore 106, may be utilized to contain equipment such as compressors for compressing any gaseous vapors in the fluid downhole. Such compressors may be utilized to compress the gas and discharge the compressed gas into a producing formation to aid the production of hydrocarbons from such a formation. Alternatively, the gas may be compressed into a liquid form and discharged into the access wellbore 20 for transportation to the surface.

In the present invention, the non-production wellbores 102, 104 and 106 are preferably, but not necessarily, formed entirely or substantially in the non-producing formations. The non-production wellbores are preferably utilized for performing desired operations downhole for improving the overall

efficiency of recovering and/or processing hydrocarbon recovery, improving the life of the various wellbores and/or reducing costly operations at the surface.

5           **FIG. 5** shows examples of the placement of flow control devices outside both the primary access wellbore 20 and the producing formations, and the placement of processing equipment in the primary access wellbore. In the example of **FIG. 5**, a separate fluid flow control device is placed in each of the production wellbores 110a, 110b and 112. Accordingly, flow control  
10       devices 300a and 300b are respectively placed in production wellbores 110a and 110b while a flow control device 304 is placed in the wellbore 112. The fluids recovered from the formations 82 and 84 pass to the access wellbore via these control devices. The fluid control devices 300a, 300b and 304 may be controlled from the surface. These flow control devices 300a, 300b and  
15       304 are preferably remotely and independently controllable from the control unit 40. These flow control devices are adjusted to optimize the production of hydrocarbons from the various producing formations. This also allows shutting down a specified production branch wellbores to perform workover or service operations. The flow control devices 300a, 300b and 304 may be  
20       made to communicate with each other so that they may automatically adjust the fluid flow from their associated wellbore according to programmed instructions. These devices may also be programmed to completely close if certain predetermined adverse conditions occur. Additionally, these flow

control devices may be operated as a function of certain parameters of interest, such as the pressure in the branch wellbores.

Still referring to FIG. 5, the above-noted devices may be deployed in the primary access wellbore 20. Devices placed in the primary wellbore are generally denoted by numeral 307. Such devices may be used for treating and/or processing fluids downhole as described above in reference to equipment 222 (FIG. 4). The equipment 307 may be utilized alone or in conjunction with materials (chemicals, etc.) stored in one of the branch wellbores, such as wellbore 106. The processing and treatment of the fluids may be done in the manner described earlier.

The use of non-producing wellbores to store devices and materials to perform desired operations, and the use of flow control devices outside the access wellbore allows the access wellbore to be maintained substantially free from devices that are not utilized for flowing fluids through the access wellbore. In other words, during the production of hydrocarbons, the access wellbore remains free of devices and materials which might negatively affect the flow of hydrocarbons to the surface.

The discussion thus far has related to the formation of multi-lateral wellbores from a primary wellbore that is formed primarily in a non-producing formation. In some applications, it may be desirable to form more than one access wellbore. FIG. 6 shows a manner of forming multi-lateral production

wellbores from an access wellbore formed in the producing formation 82. In this configuration, the access wellbore 20 is formed as described above with in reference to FIG. 1. Additionally, the remaining wellbores are formed as described in reference to FIGS. 2-5 with the exception of wellbores 110a and 110b. Instead, a second access wellbore 402 is formed from the access wellbore 20 into the formation 82. A desired number of lateral wellbores 404a-d are then formed from the access wellbore 400 into the producing formation 82. Seals 406a-d are formed between the access wellbore 402 and branch wellbores 404a-d respectively. These seals are formed within the producing formation 82 by any suitable method known in the art. The branch wellbores are 404a-d are respectively completed at zones 408a-d. Fluid flow control devices are preferably placed in each of the producing branch wellbores to independently adjust the fluid flow through each such production wellbore. In each of the wellbore configurations herein the various fluid flow control devices may communicate with each other to control the corresponding fluid flows and/or may be controlled independently from a remote location such as the surface.

FIG. 7 shows an alternative method of forming wellbores. In this method, the primary wellbore 20 is formed away from some of the reservoirs, such as reservoirs 82 and 84, and drilled into some of the reservoirs, such as a reservoir 420. Hydrocarbons from the formations 82, 84 and 420 may be produced in the manner described above or by any other known method.

Such a method is useful when it is desired to drill the primary access wellbore into one or more reservoirs, such as reservoir 420, and avoid drilling it in to one or more reservoirs, such as reservoirs 82 and 84. Such a method allows placing the primary access wellbore along an optimal path and allows the production of hydrocarbons from each such reservoir. It should be noted that additional access wellbores (not shown), similar to the wellbore 112, may be formed from the primary access wellbores into the reservoir 420.

FIGS. 8A and 8B show the use of multi-paths for flowing fluids through the access wellbore 20. FIG. 8A shows two concentric conduits or tubings, having an outer tubing 450a and an inner tubing 450b. More than two concentric tubings may also be utilized. These concentric tubings may be utilized instead of the single tubing 240 as shown in FIGS. 4 and 5. Fluid flow control devices 452a and 452b are installed respectively in tubings 450a and 450b to control the flow of the fluids through their associated tubings. Such an arrangement allows for better control of the fluid flow compared to the single tubing 240. New wellbores tend to produce larger amounts of hydrocarbons, which amounts gradually reduce as the producing formations are depleted. In such cases, for high production rates, the larger (outer) tubing 450a alone or in conjunction with the inner tubing 450b may be utilized for flowing fluids to the surface. This may be accomplished by opening the devices 452a and 452b. As the fluid flow decreases due to change in pressure or due to the increased amount of water production, one of the

tubings may be closed. Additionally, this arrangement may be utilized to flow different materials to the surface. For example one of the tubings may be utilized to flow water and solids to the surface and the other tubing for flowing hydrocarbons.

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**FIG. 8B** shows an alternative arrangement of utilizing multiple tubings in a wellbore. **FIG. 8B** shows the use of two different sized tubings 470a and 470b placed side-by-side in the access wellbore 20. Fluid flow control valves 472a and 472b are respectively placed in the tubings 470a and 470b for  
10 controlling the fluid flows through their respective tubings. The flow through these tubings may be controlled by independently controlling the flow control devices 472a and 472b. The flow control valves shown in **FIGS. 8A** and **8B** are preferably remotely controllable from the surface. The above described arrangements provide for better control of the flow of fluid through the access  
15 wellbore 20 over the life of the producing wellbores without requiring secondary work to insert smaller tubings after the completion of the access wellbore 20.

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**FIGS. 9A** and **9B** show an apparatus which may be utilized for placing into and retrieving from any of the wellbores equipment and materials. **FIG. 9A** shows an access wellbore 510 having an inside diameter " $d_1$ " and branch wellbores 512a-c with respective diameters  $d_{2-4}$ . Each of the diameters  $d_{2-4}$  is smaller than the diameter  $d_1$ . The device or tool 520 to be moved into a



desired branch wellbore is detachably attached or coupled to a carrier 522. This can be accomplished by making the size of the carrier 522 greater than each of the openings 514a-c. The dimensions of the carrier are such that it may be passed over the branch wellbores 512a-c. To convey the device 520 into a desired wellbore, the carrier 522 is coupled to a conveying device 524, such as a tubing. The device 520 is coupled to the carrier 522 or the conveying device 524. The conveying device is then moved in the wellbore 510 to position the carrier 522 before the desired wellbore. For example, if the device 522 is to be conveyed into the wellbore 512b, the carrier is positioned as shown by the dotted lines 522' before the wellbore 512b. The carrier 520 is then detached from the conveying device 524 while leaving the device 520 attached to the conveying device 524. The device 520 is then conveyed by the conveying device into the wellbore 512b. Since the device 52 is smaller than the opening of the wellbore 512b, the device 520 may be conveyed in to the wellbore by utilizing any of the techniques known in the art. After the device 520 has been properly positioned in the wellbore 512b, the conveying device is detached from the device 520 and used to retrieve the carrier 522 from the access wellbore 510. To retrieve a device from any of the wellbores, the process described above is reversed. Fluids, such as chemicals and other materials, may also be conveyed into a desired wellbore in the manner described above.

In an alternative embodiment, as shown in FIG. 9B, the carrier 540 includes a number of adjustable members 532, each member preferably being independently adjustable radially. Such members may be mechanically adjustable or remotely adjustable so that they expand and collapse about the body 530. To convey a device, the adjustable members are moved to suitable positions to convey the device 520. If remotely adjustable members are utilized, the carrier may not need to be detached prior to conveying the device into a destination wellbore. If the destination wellbore is sufficiently large to accommodate both the carrier and the device to be conveyed, then the combination may be conveyed into the destination wellbore and the carrier detached after positioning the device in the destination wellbore. Such a carrier may be utilized to retrieve a device from the wellbore with the members collapsed to the body, which are then expanded to pass over other branch wellbores and repositioned to convey the device into a second wellbore.

While the foregoing disclosure is directed to the preferred embodiments of the invention, various modifications will be apparent to those skilled in the art. It is intended that all variations within the scope and spirit of the appended claims be embraced by the foregoing disclosure.

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Claims

- 5     1.    A method of producing a hydrocarbon from a subsurface formation comprising:
- (a)   forming a wellbore into the subsurface formation for producing the hydrocarbon therefrom; and
- 10        (b)   converting downhole the hydrocarbon produced into a refined material having chemical structure different from the hydrocarbon produced from the subsurface formation.
- 15     2.    The method as claimed in claim 1, wherein the refined material is octane.
3.    The method as claimed in claim 1, wherein the refined material is benzene.
- 20     4.    The method as claimed in claim 1, wherein the refined material is toluene.
5.    The method as claimed in claim 1, wherein the refined material is methanol.
- 25     6.    The method as claimed in any preceding claim, wherein the conversion of the hydrocarbon is done in a branch wellbore.



INVESTOR IN PEOPLE

Application No: GB 0010317.6  
Claims searched: 1-6

Examiner: David McWilliams  
Date of search: 21 June 2000

**Patents Act 1977**  
**Search Report under Section 17**

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK CI (Ed.R): E1F: FAB, FMU

Int CI (Ed.7): E21B 43/00, 25, 30

Other: ON-LINE: EPODOC, JAPIO, WPI

**Documents considered to be relevant:**

Category	Identity of document and relevant passage	Relevant to claims
X,P	WO 96/30625 A1 BAKER HUGHES (see claim 40, page 19 lines 9-27, figure 11)	1,6

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.